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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Four papers were published during the ensuing period of this grant. One paper reviewed the connection between monospline functions and optimal quadrature formulae and demonstrated their application to the estimator implementation problem. Another paper showed how Gauss quadratures could solve discretization problems which are inherently a part of any numerical approach. The third paper developed the theory for applying optimal quadrature formulas to the nonlinear estimation problem. Finally, the problem of obtaining the parameters for the formulas used in the optimal quadrature method was solved. For additional

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20. Abstract

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FINAL REPORT

# NUMERICAL IMPLEMENTATION METHODS FOR NONLINEAR ESTIMATORS

Grant AFOSR 75-2828 and Modifications Nos. 1 and 2

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Principal Investigator



March 1978

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Final Report

NUMERICAL IMPLEMENTATION METHODS FOR NONLINEAR ESTIMATORS

This final report will be composed of a review of results obtained from the grant as they have appeared in publications in the open literature. Copies of the publciations have in some cases already been supplied to AFOSR as they became available. In other cases they have been accepted for publication or are submitted but have not yet appeared. The results are reviewed below.

Preliminary results on the problem of nonlinear estimator implementation using optimal quadratures were reported by Liang and Klein in the Symposium on Nonlinear Estimation, September 1975 (1). This paper reviewed the connection between monospline functions and optimal quadrature formulae and demonstrated their application to the estimator implementation problem, the objective of this effort. It also identified important members of the optimal quadrature formula class, in particular, those originally studied by Gauss. Finally, the paper analyzed the errors incurred by using several of these types of numerical formulas in integrating several analytical functions of interest.

A definitive paper on the application of Gauss' formulas was published in IEEE/AC transactions (2) in 1977. This paper showed how Gauss quadratures could solve discretization problems which are inherently a part of any numerical approach. It then discussed the probability density products encountered in the updating process and showed how the numerical approximation of the updating integral could be performed. It also analyzed the errors resulting from the several major sources in accomplishing this result.

The theory for applying optimal quadrature formulas to the nonlinear estimation problem has been submitted for journal publication (3) and it is exptected that these results will appear in the future.

To use the optimal quadrature method, one must have available the parameters for the formulas employed. Prior to our work, these parameters were only available for a small set of cases. The computation of the parameters for a large number of other cases was required in order to be able to generally apply the method. However, the calculation of these defining parameters is a significant numerical task in itself. This problem was solved and a paper (4) describing the method is to be published.

## REFERENCES


1. Liang, J. Y., and R. L. Klein, "Nonlinear Estimation Implemented with Optimal Quadrature Formulae," Symposium on Nonlinear Estimation Theory, San Diego, California, September 1975.

2. Klein, R. L., and A. H. Wang, "Gauss Quadrature Estimators," IEEE Transactions on Automatic Control, Vol. AC-22, No. 1, Feb. 1977, pp. 70-73.

3. Wang, A. H., and R. L. Klein, "Optimal Quadrature Formula Nonlinear Estimators," submitted for journal publication.

4. Klein, R. L., and A. H. Wang, "A Numerical Method to Obtain Optimal Quadrature Formulas," accepted for publication in International Journal for Numerical Methods in Engineering.